DEMOGRAPHY OF SHORT-TAILED SHREW POPULATIONS LIVING ON PCB CONTAMINATED SITES

RUDY BOONSTRA

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Abstract: In ecological risk assessment, a key necessity is to understand how contaminants known to have negative impact on laboratory mammals affect the population demography of mammals living in their natural environment. We examined the demography of six local populations of the short-tailed shrew *(Blarina brevicauda)* living in eastern deciduous forest palustrine habitat along the Housatonic River, Massachusetts on soils contaminated with a range of PCB concentrations (1.5-38.3 ppm). The objective of the study was to assess whether PCBs adversely affect the population demography of these small mammals living in their natural environment. *Blarina* were selected for study because they would be expected to readily bioaccumulate PCBs from the soil. Populations were intensively live-trapped on 1 ha grids from spring to autumn 2001. There was no relationship between any demographic parameter and PCB concentrations. Densities were high (usually exceeding 20/ha, and on two grids exceeded 60/ha in summer), survival was good (typically 60-75% per 30 days), and sex ratio, reproduction rates, growth rates and body mass were within the range reported in the literature. Thus, these shrew populations showed no detectable impact on their population demography from living on PCB-contaminated sites.

Keywords – Shrews, Contamination, Polychlorinated biphenyls, Population Effects, Natural Environment

INTRODUCTION

The short-tailed shrew, *Blarina brevicauda,* is the largest shrew in North America and is one of the most common small mammal species in the eastern deciduous forests [1,2]. They are semifossorial mammals, with runways in the top 10 cm of the soil, and spend little time on the ground surface [3]. Food appears to be the major limiting factor in woodland habitats [4]. Although *Blarina* avoid areas with little cover and with extremes in temperature and moisture, specific types of vegetation, cover, temperature, and moisture have little effect on local distribution. They are more common in areas with more than 50% herbaceous cover [5]. Their high metabolic rate requires that they consume over half their body weight in food daily [6]. Earthworms, slugs, and insects are the major prey items, though spiders, molluscs, and some vertebrates (other shrews, snakes, salamanders, and voles) are also eaten [7-9]. Thus *Blarina's* life history, diet, high metabolic rate, and high food consumption rate make it an ideal bioindicator species to assess the ecological risk of bioaccumulative chemicals such as polychlorinated biphenyls (PCBs) and their impact on demography in natural populations.

PCBs are organochlorines that are persistent, highly lipophilic, and widespread throughout the environment [10]. They bioaccumulate in the food chain and therefore higher trophic level animals have higher potential for exposure. Since PCBs adsorb strongly to organic

matter [11] which is eaten by earthworms and earthworms are a major part of the diet of *Blarina,* PCBs should bioaccumulate readily in *Blarina.* Indeed, PCBs are known to accumulate in earthworms [12]. Most of the field evidence for bioaccumulation on PCBs in *Blarina* is suggestive, but anecdotal, coming from accidentally contaminated sites [13,14]. In contrast, the field evidence in European shrews is more convincing [15-17]. The best evidence of the potential for bioaccumulation in *Blarina* in North America comes from research on long-term studies of the organochlorine DDT. Relative to other small mammal species, the highest DDT concentrations and longest persistence occurred in *Blarina* populations [17-21]. Thus, given the PCB evidence from Europe and that on DDT from North America, bioaccumulation of PCBs in *Blarina* is expected.

Laboratory evidence indicates that PCB contamination can detrimentally affect mammalian physiology [22,23]. Studies on domestic rodents and on *Peromyscus* spp. indicate that, under some exposure conditions, PCBs have negative impacts on both growth and reproduction [11,24-26]. A critical unknown is the extent to which laboratory toxicity studies and field studies on bioaccumulation can be used to predict PCB-mediated population level impacts on *Blarina* in the environment. Laboratory experiments may exaggerate the potential impacts of the PCBs because they employ uniform levels of exposure, whereas in the natural world, the distribution of PCB can be highly patchy. The evidence that the sublethal effects observed in the laboratory alter demography in the field is not strong [27]. To date, virtually all field studies on the impact of PCBs on small mammals have focused on voles and various *Peromyscus* spp. and there were either no or minor negative impacts [27] or impacts were confounded by the presence of other contaminants [28,29]. There is thus a critical need for a comprehensive, population level study of *Blarina* in an area where PCBs are the primary contaminant and where there are elevated concentrations of PCBs in the soil.

The Housatonic River floodplain provides such a site. It is located in Berkshire County MA and was contaminated with PCBs downstream of the GE facility at Pittsfield. Between 1937 and 1977, GE used PCBs (primarily Aroclors 1254 and 1260) as an insulating medium in transformer applications [30]. Elevated levels of PCBs ($\geq$ 1ppm) are restricted primarily to the river sediments and to the soils in the 10-year floodplain. In the soils, there is a wide range of PCB concentrations and thus the exposure of mammals may be site dependent.

The goal of our research was to assess the impact of PCB contaminants on natural populations of *Blarina* exposed to a range of PCB concentrations. Although the terrestrial ecosystems along the Housatonic River have been characterized during previous studies [30,31], only anecdotal information on *Blarina* was collected. Since laboratory studies have indicated that small mammal reproduction and growth are particularly sensitive to PCB effects [11,24,25], our goal was to study *Blarina* populations over one breeding season to examine these parameters and their impacts on demography and population structure.

STUDY GOALS AND DESIGN

The objective of this study was to live-trap breeding populations of *Blarina* living on areas contaminated with a range of PCB concentrations in order to compare populations present in areas with high versus low PCB concentrations. The endpoints assessed were demographic parameters that could potentially be affected by PCB exposure - density, survival, rates of reproduction, sex ratio, and growth rates – and these may be modified by site specific effects such as differences in exposure to flood events and habitat quality. Since no study has examined the impact of PCBs on these demographic parameters in *Blarina,* we have reviewed findings from other small mammal species, principally from the laboratory and from one *in situ* field study [27]. Based on these findings, we hypothesize that if PCB exposure is negatively affecting

Blarina populations, population density will be lower on sites with higher PCB soil concentrations (because of reduced survival and reduced reproduction [24,32], frequency of reproduction should be curtailed and should be exposure dependent [25,32], and body growth should be lower [24,25]. Ideally, we would also have liked to quantify the rates of production and survival of young produced on each site, but this was not possible for two reasons. First, unlike voles which typically enter the traps shortly after they are weaned and weigh $\leq$ 50% of adults [33], young *Blarina* do not enter traps until they are virtually adult size (at least three-fourths grown - [34]). Thus, the source of new animals (on-site reproduction or immigration) cannot be known with confidence. Second, by their nature floodplains are regularly inundated [35,36] and thus, over the portion of the breeding season subject to floods, young may not be produced on site. Nevertheless, strategic livetrapping during a portion of the breeding season not subject to flooding should permit a rigorous, quantitative assessment of other critical population parameters.

In addition, since previous research indicates no consistent trend on the impact of floods on small mammal populations, with impact ranging from minor or of short duration [35,37] to severe [38], we cannot make a definitive hypothesis on the impact of flooding. But in all these studies the focus of the research were the potentially arboreal *Peromycus* spp., which could escape by climbing trees. *Blarina* does not have this option and thus we expected their populations to be markedly reduced, relying on recolonization from high ground. Finally, habitat quality will also affect densities, acting largely through presence of food [4] and to some extent ecover [5] and we can expect this to influence our results. We tried to deal with this by having trapping grids that differed only in PCB concentrations, but not habitat quality.

Our study was designed to assess *Blarina* populations during that portion of the breeding season that was flood free, after a sufficient delay to permit recovery from the major flood event occurring in the early spring after snowmelt. We allowed approximately 4-6 weeks to elapse after the spring flood and before the first trapping session to permit recolonization of the floodplains. Environmental constraints thus determined when the first trapping session occurred. We trapped intensively three times over the flood-free period with a technique designed specifically for *Blarina* involving multiple checks of the traps during the day to minimize the length of time the animals were in the traps and no overnight trapping (traps were locked open on the last check of the day) to prevent trap-induced mortality.

Our study evaluated *Blarina* on sites with a wide range of soil PCB concentrations, but employed no reference populations on PCB-free floodplains as previous reconnaissance [31] indicated there are no suitable areas with similar vegetation types and sufficient area within an 80 km radius. Thus we employed published studies as benchmarks with which to compare our findings.

STUDY SITE

Grid Site Selection

The study took place in the spring, summer and autumn of 2001 in western Massachusetts along a 16 km reach of the Housatonic River between Pittsfield and Woods Pond (Fig.1a). All potential sites within the 10-year floodplain of the river were explored. Following this exploration, six sites were selected based on PCB concentrations, habitat uniformity, and sufficient area to permit a 1 hectare (ha) trapping grid to be located within each area. Two grid classes were selected, designated as low PCB grids and high PCB grids, with

three sites in each class. A spatially weighted average PCB concentration was calculated for each grid using the method decribed by Chow et al. [39] and using soil concentration data collected by the EPA and GE (http://www.epa.gov/region01/ge/thesite/restofriver-maps.html and data from EPA CD-ROM: 030102_usepa_hr_dbase1.mdb). Only concentrations in the top 15.24 cm of the soil horizon (where *Blarina* are active) from sampling points within the trapping grid and a 33 m buffer around the grid were used to obtain these averages. The 33 m buffer around the grid was a conservative estimate of how far *Blarina* would typically move during their daily activities. In fact, the mean within trapping session movement of *Blarina* over the entire study was 11.04 m $\pm$ 1.21 (N=156), with males moving significantly longer distances than females ($F=7.19$, df 1,154, $P < 0.008$; males – 14.15 $\pm$ 1.94, N=74; females – 8.23 $\pm$ 1.14, N=82). The low PCB grids had spatial average concentrations ranging between 1.5 and 2.5 ppm and the high PCB grids had concentration ranging between 17.6 and 38.3 ppm (Table 1).

All sites were located within the eastern deciduous temperate forest biome in primarily palustrine habitat (as designated on EPA habitat classification maps) with portions of two grids (grids 3 and 5) also including upland habitat. However, differences in habitat did occur as all high PCB sites were immediately adjacent to the river and subject to increased frequency of flooding and scouring associated with the flooding events whereas all low PCB sites were on slightly higher ground some distance from the river. Four of our sites overlapped with or were near those of previous small mammal studies in this area. Grid 1 was in the same area as site 1B used by TechLaw, Inc. [30] and grid 2 was adjacent to it. Grid 5 was on the same floodplain forest site used by ChemRisk [31] and by TechLaw, Inc. [30] (site 8). Grid 3 was just down river of site 3 used by TechLaw, Inc. [30]. The descriptions of site vegetation provided below are derived from the TechLaw, Inc. (1999) analysis and from our visual assessment.

Grid Site Location and Description

Grid 1 (Fig. 1b): This grid was classified as a high PCB contamination site (spatial average PCB concentration = 33.5 ppm). It is on the east side of the confluence of the east and west branches of the Housatonic River and near the end of Brunswick St. It is bisected by a power transmission line and a drainage ditch and borders the river. The canopy layer was dense and the dominant canopy trees were silver maple *(Acer saccharinum),* box-elder *(Acer negundo)* and American elm *(Ulmus americana);* the dominant shrubs were winged and European euonymus *(Euonymus alatus, E. europaea),* European privet *(Ligustrum vulgare)* and Morrow's honeysuckle *(Lonicera morrowii);* the herbaceous layer was varied, with the dominants being Japanese knotweed *(Fallopia japonica),* ostrich fern *(Matteuccia struthiopteris),* and golden alexanders *(Zizea aurea),* with sensitive fern *(Onoclea sensibilis)* and false nettle *(Boehmeria cylindrica*) also being common. The ground humus/leaf layer was well developed. TechLaw, Inc. [30] describes the vegetation in detail for this site (TechLaw site 1B).

Grid 2 (Fig. 1b): This grid was classified as a low PCB contamination site (spatial average PCB concentration = 2.5 ppm). It is also on the east side of the river at least 100 m from grid 1 and had similar vegetation. The ground humus/leaf layer was well developed.

Grid 3 (Fig. 1c): This grid was classified as a high PCB contamination site (spatial average PCB concentration = 17.6 ppm). It is on the west side of the river on Sewage Treatment Plant property. The vegetation was heterogeneous, with the canopy layer fragmented and with large, herb-filled openings. Dominant canopy trees were silver maple and box-elder though eastern hemlock *(Tsuga canadensis)* was also common on the higher bench; shrubs were uncommon; and dominant herbs included ostrich fern, sensitive fern, false nettle and wood nettle *(Laportea canadensis).* TechLaw, Inc. [30] describes the vegetation in detail for a site just upstream from this site that appeared to be similar (TechLaw site 3).

Grid 4 (Fig. 1d): This grid was classified as a high PCB contamination site (spatial average PCB concentration = 38.3 ppm). It borders the east side of river and is just north of the New Lenox Road bridge. The vegetation was heterogeneous varying from densely canopy-covered areas with primarily hawthorne (*Crataegus* spp.) and apple (*Malus pumila),* to dense shrub stands of silky dogwood *(Cornus amomum),* and to grassy meadow areas with some white pine.

Grid 5 (Fig. 1e): This grid was classified as a low PCB contamination site (spatial average PCB concentration = 2.2 ppm). It is on the west side of the river near the railroad tracks and south of New Lenox Road. The vegetation was reasonably homogeneous, with the dominant canopy tree being red maple *(Acer rubrum),* but trembling aspen *(Populus tremuloides),* black cherry, *(Prunus serotina),* and white pine *(Pinus strobus)* were present in low numbers; the shrub layer was reasonably dense consisting of red maple and black cherry saplings and a variety of shrubs including northern arrowwood *(Viburnum dentatum);* common herbs included cinnamon fern *(Osmunda cinnamomea),* swamp dewberry *(Rubus hispidus),* and royal fern *(Osmunda regalis).* TechLaw, Inc. [30] descibes the ground vegetation in detail for this site (TechLaw site 8).

Grid 6 (Fig. 1f): This grid was classified as a low PCB contamination site (spatial average PCB concentration = 1.5 ppm). It is approximately 1.6 km north of Woods Pond and on the west side of the river. It borders on a river backwater on its east end and on railroad tracks on the west end. Vegetation was heterogeneous varying from solid canopy cover to more open woodland, with about one third of the grid having grass hummocks and moist soil conditions. Dominant canopy cover included white pine, red oak *(Acer rubra),* and black ash *(Fraxinus nigra);* shrub cover was minimal and the rest of the vegetation was similar to grid 5.

METHODS

Environmental Constraints

Heavy late winter snows in the Pittsfield area resulted in a significant snow pack in early April (0.5 m snow on meadows on 3 April 2001). Snowmelt occurred shortly thereafter and was followed by severe flooding in mid-April (16-17). The flood waters subsided by late April-early May so we delayed setting up the trapping grids until late May (grid site selection occurred between 22-24 May) and the first trapping session took place between 29 May and 6 June. A brief flood again occurred in early June, inundating grids 2, 4, 6, most of 3, and some of 1; grid 5 remained mostly dry. Trapping had been completed on grids 1,2, and 5 before the flood hit, but the flood prevented trapping on the other three areas. The second (16-28 July) and the third (6-24 September) trapping sessions were conducted over longer period of time because all grids were trapped.

Live Trapping

All grids had 100 grid points (at 10 m intervals), and covered 1 ha of forest (except for grid 3 which was 1.04 ha), but not all grid points were arranged in a 10x10 pattern. Grids were fit as efficiently as possible into the section of forest chosen. Grid area included a 5 m wide area (half the distance between traps) around the perimeter of each grid. Grid setup took approximately 8 days. All grid points were marked by semi-permanent, orange surveying, 1 m flags, with the proper grid coordinate displayed on each. Fifty Longworth live traps were placed on each grid at every second point, starting at A1. Traps were placed as close to the grid stake as possible where sufficient protection from the elements was provided. Fallen bark or ferns were placed on top of the traps to provide more shade. All traps were baited with crimped oats.

Each grid was prebaited for one day prior to trapping to habituate small mammals to the traps. During the prebaiting period, traps were locked open and a small amount of crimped oats was placed in the nest box. During the trapping session, traps were set at first light (in spring and summer this was completed by 0600 hrs; in autumn this was completed by 0700 hrs because of declining daylength) and then checked as frequently as possible (4 times in spring and summer - at 0900, 1200, 1500 and 1800 hrs - and 3 times in autumn – at 1000, 1330 and 1700 hrs). At the end of each day, the traps were locked open to prevent capture of animals overnight. Over the course of the study, we planned to trap each grid three times – in spring, summer, and autumn, but because of severe flooding part way through the spring session, only three grids were trapped three times, and the other three were trapped twice. During each trapping session, each of the grids was trapped for three consecutive days. We attempted to trap two grids simultaneously, but weather and logistics prevented

this on occasion. Traps were removed at the end of the third day, scraped out, rebaited, locked open and placed on the next two grids for prebaiting. This was repeated until all six grids were trapped. Traps used on high PCB contaminated grids were used only on other high PCB contaminated grids, and likewise for low PCB contaminated grids.

On first capture, all the short-tailed shrews were marked with a unique number by toeclipping (no more than two toes on each of the hind feet) and, on first capture in each trapping session, sex, sexual condition (females lactating or not; males breeding or not), mass, and location were obtained. Females were identified by the presence of nipple scars. Lactating females were distinguished from nonlactating females by their prominent nipples sticking up beyond the level of the fur line and slightly lighter colored skin surrounding the nipple. Females were identified as pregnant when they were pear-shaped. If no nipple scars were found, the animal was identified as a male and this was confirmed by extracting the penis by gently pressing down into the abdomen and pushing back towards the tail. Although males have no scrotum, when breeding their enlarged testes were readily evident as prominent protrusions in the inguinal area. If not obvious, we would gently press on the rear abdominal area to force the testes toward the tail to determine testes size. We did not attempt to distinguish overwintered animals from young of the year for two reasons. First, since we did not start trapping until late May, a pure overwintered cohort could not be determined on the basis of animal mass or pelage condition. By that time, the population could have already been breeding for at least two months and for up to four months if the late winter conditions prevailed that Christian [40] found in New York. Second, young of the year do not enter traps until they are at least three-fourths grown [34] and only 5 of the 240 new animals caught weighed less than 15 g. Thus it was not possible to obtain recruitment of young to the population as a function of the number of adults present. To obtain an index of how far shrews moved during their daily activities (foraging, territorial defense, etc.), we calculated the maximum distance moved between capture locations within a trapping session.

Population analysis

Population estimates and standard errors were obtained using a mark-recapture heterogeneity (jackknife) model [41] from the program Capture [42]. This is a closed population estimator and thus assumes that there is no mortality and no immigration or emigration during the sampling period. It is a robust method for estimating population size, is recommended by Menkens and Anderson [43] and Boulanger and Krebs [44], and is widely used and accepted in population studies (e.g. 45). The standard errors resulting from these estimates are not equivalent to sampling error and thus power analyses to compare population estimates could not be done.

Survival was assessed in two ways. If an animal disappeared from the trapping grid, we cannot know if it died or emigrated and thus mortality is equated with disappearance. In the first analysis, survival rates were measured by direct enumeration of marked animals [46]. These rates were calculated as the percentage of animals recaptured at time 2 that were released at time 1 and are expressed as the minimum survival rates per 30 days to permit comparisons to other live-trapping studies of *Blarina*. The true survival rate should never be less than these rates. In the second analysis, a logistic regression was carried out for the period between mid-July and September. A similar analysis was not conducted between late May-early June and mid-July because of the possible negative effects following flooding during the first trapping session. Survival was determined between trapping sessions two to three based on recapture. These results were recorded for each animal as a binary datum (recaptured/surviving = 1,

disappearing= 0). This technique converted binary data from individuals into probability values by fitting a logistic curve through available points [47,48]. The analysis involved a logistic regression with the factors - grid and sex - as the main effects. Animals were included in the analysis if they had been released from the trap in session two in a healthy condition. On several of the days in that session, heavy rains resulted in some animals becoming wet in the traps, suffering the effects of hypothermia, and, though none were dead when they were removed from the traps, some were very weak. We noted these animals and removed them from the analysis.

To assess reproduction, animals were defined as potentially being in breeding condition based on their body mass. In males, all animals weighing $\leq$ 19 g were excluded from the analysis as only 3 of 42 males less then or equal to this weight were classified as being breeding condition (enlarged testes). In females, no animal less than 18 g was found to be lactating and thus all animals $\geq$ 18 g were included as potentially breeding. As only 3 females could be positively identified as pregnant, this was a poor index to discriminate among treatments. Differences among trapping sessions, grids, and among areas (high versus low PCB concentrations, as above) were analyzed by logistic regression. The reproductive status for each animal was recorded as a binary datum (reproductive =1, nonreproductive =2).

To assess how weight dynamics were affected on our trapping grids, we carried out two analyses. First, instantaneous growth rates per day were calculated for all animals caught in more than one trapping session. Instantaneous growth rates are simple conversions of finite rates [49] and are used widely for small mammals [e.g. 46]. Because so few animals caught in session one were caught again in session two, these data were not used and the analysis was carried out only on growth rates between sessions two and three. The analysis required an ANCOVA, with weight as the covariate, as younger animals grow more rapidly than older ones. Second, differences in mean body weights among the populations were compared. However, this latter analysis is less robust than the first one since some animals were represented in more than one trapping session (i.e. the samples were not strictly independent). Again, only trapping sessions two and three were included in the analysis as sample size was too small for session one.

Statistical Analysis

All statistical tests were performed according to procedures in Zar [50] and Sokal and Rohlf [51]. All ANOVAs and post-hoc tests (Tukey-Kramer), were performed with Statsview [52]. In general, the statistical approach involved three analyses. First, as *Blarina* populations on our trapping grids were exposed to a gradient of PCB conentrations (range 1.5 - 38.3 ppm, Table 1), we assessed exposure-response relationships for demographic parameters using simple correlation analyses. Second, grids were classified as to whether they had high (> 17.5 ppm) or low (<2.5 ppm) PCB soil concentrations and each grid was treated as a replicate of these two categories. Third, we assessed whether there was an area effect (two northern grids versus the four southern grids) as the vegetation and undergrowth was more lush in the northern grids and each grid was treated as a replicate of these two categories. Binary data (survival and breeding condition in males and females) were analyzed by logistic regression using log-likelihood ratios to test for effects as implemented in JMP [53]. Power analyses were performed by Statsview [5] and by PASS 6.0 [54]. All means are expressed as ± 1 SE.

RESULTS

Species Captured

Nine small mammal species were caught along the Housatonic River during the summer of 2001 (Table 2), but only one, the short-tailed shrew (*Blarina brevicauda),* was ubiquitous and abundant on all grids (≥ 28 different individuals). The meadow vole (*Microtus pennsylvanicus)* was reasonably common on four grids (≥ 10 different individuals) and particularly abundant on grid 4, as it had plentiful grass cover in certain sections. Five species were caught less frequently: the white-footed mouse (*Peromyscus leucopu),* the southern red-backed vole (*Clethrionomys gapperi),*the meadow jumping mouse (*Zapus hudsonius),* the pine vole (*Microtus pinetorum),* and the eastern chipmunk (*Tamias striatus).* Two short-tailed weasels and one red squirrel were also caught. Since our trapping was restricted to the daylight hours, our sampling technique did not target species that are largely nocturnal - the white-footed mouse, the southern red backed vole, and the meadow jumping mouse - and thus little can be said about their actual presence on the grids. Eastern chipmunks are diurnal and were found at low abundance on five grids.

Population Changes of Blarina

Population densities per ha of the short-tailed shrew on the six grids ranged from a low of 8 animals in May-June to a high of 67 in July (both estimates from grid 1) (Table 3). Figure 2 shows that there were two clusters of grids with respect to density changes - the two northern grids showed a pronounced population fluctuation whereas the four southern ones remained remarkably constant. The two grids nearest Pittsfield (grids 1 and 2) fluctuated in parallel over the summer, increasing 3-8 times from May-June to July and then declining 42-57% by mid-September. The only grid of the other four that was trapped at all three times – grid 5 - remained constant over time (range 19-22); in late spring it had slightly higher densities than the northern grids, showed no mid summer increase, and showed no autumn decline. Though we have only two estimates for the other three grids, all remained remarkably constant, increasing only 4-22% from summer to autumn.

A simple correlation of *Blarina* population size (Table 3) on PCB levels on the grids (Table 1) showed no relationship in either summer (r=0.30, N=6, P=0.56, power=0.09) or autumn (r=0.54, N=6, P=0.27, power=0.20), though in both cases the direction of the relationship was the opposite to that expected. A spring relationship could not be calculated because only 3 grids were trapped. When the trapping grids were split into high and low PCB concentrations, a repeated measures ANOVA on trapping sessions two and three also showed no evidence of an effect of PCB concentrations (F=0.43, df 1,4, P=0.55), but power was low (0.08) because of low sample size and high variance among the grids. To assess the importance of an area effect independent of PCB concentrations, the grids were separated into the two northern grids (1 and 2) and the four southern grids (3-6) and a repeated measures ANOVA was performed on trapping sessions two and three. The area effect was highly significant (F=19.69, df 1,4, P=0.01) and power was high (0.91). Hence area, not differences in PCB concentrations, explained most of the differences among the grids in population estimates.

Survival

The 30-day survival estimates between sessions one and two (Table 4) were variable, being affected by small sample size and probably by the early June flood event. Even though animals were forced to move away from the grids following the flood, some showed high site fidelity and were subsequently caught again in the second trapping session on the same grid as during the first trapping session. On grid 1, 2 females and on grid 2, 3 males and 1 female were caught before (May-June) and after (July) the flood. Grid 5 experienced minimal effects of this flood event and 5 males and 2 females were caught both times. A few animals were caught on

these grids in all three trapping sessions (1 female on grid 2, 1 female and 5 males on grid 5). Between sessions two and three, there were marked differences in survival among grids, with that on grids 1, 5, and 6 being the highest and that on grid 4 the lowest (Table 4). On the former grids animals were living almost three times as long as on the latter grid, with half surviving about 72 days on the former grids versus only about 22 days on grid 4. A simple correlation of population size on PCB levels on the grids showed no significant relationship between PCB concentrations and survival from summer to autumn for either males (r=-0.62, N=5, P=0.27, power=0.20; grid 3 excluded as only one male was caught in summer) or females (r=-0.58, N=6, P=0.23, power=0.23).

In the logistic regression analysis of survival, a two-factor model (grid and sex) was used. There was a significant difference in survival among grids ($\chi^2 = 15.62$, df = 5, $P = 0.008$), no difference between the sexes ($\chi^2 = 1.36$, df = 1, $P = 0.24$), and no interaction effect ($\chi^2 = 2.07$, df = 5, $P = 0.84$). Thus males and females showed similar survival from mid summer to autumn within a trapping grid. To evaluate whether the differences among grids were the result of differences in PCB concentrations, grids were pooled and classified as having high or low PCB concentrations as defined above. There was no difference in survival between high or low PCB sites ($\chi^2 = 1.03$, df = 1, $P = 0.31$), and thus the grid effect was related to factors other than PCB concentrations.

Sex Ratio

Changes in the sex ratio may give insight into the breeding structure of the population and whether there are differential effects of PCBs on one sex (Table 5). In trapping session one, there was no difference among the grids ($G^2 = 0.67$, df 2, P = 0.71) with 35.5% (N=33) of animals being male. In session two, there was a significant difference among grids ($G^2 = 15.76$, df 5, P = 0.008), but this was a result primarily of a strongly skewed sex ratio on grid 3 (only 1 of 15 animals was a male). When this grid was excluded, there was no difference among grids in session two ($G^2 = 4.09$, df 2, P = 0.39), with 48.6% (N=138) being male. In session three, there was no also difference among grids ($G^2 = 7.63$, df 5, P = 0.18), with 40.4% (N=136) being male. However, for sessions two and three, grids 1 and 2 had 10-20% more males than the other grids (Table 5). As with the population analysis, the data from the two northern grids (1 and 2) were pooled and compared with that from the pooled sex ratio on the other four grids. In both cases, there was a significant difference between these two clusters (session two - $G^2 = 8.03$, df 1, P = 0.005 with 55.0% being male on the northern grids and 32.4% being male on the four southern grids; session three - $G^2 = 5.52$, df 1, P = 0.02 with values being 52.8% and 32.5% respectively). To assess whether PCB concentrations affected sex ratio, only sessions two and three were examined. A simple correlation analysis of sex ratio on PCB concentrations in the grids showed no significant relationship between PCB concentrations and sex ratio in either summer (r=-0.22, N=6, P=0.68, power=0.07) or autumn (r=0.14, N=6, P=0.79, power=0.06). When the grids were pooled by PCB class (high vs. low), there was again no evidence of a difference in sex ratio as a function of PCB concentrations (session two - $G^2 = 1.89$, df 1, P = 0.17; session 3 - $G^2 = 0.002$, df 1, P = 0.96). Thus, there were area effects on sex ratio, but no effect of PCB concentrations.

Reproduction

Reproductive parameters are expected to show strong seasonal effects and may also be affected by PCB concentrations in the environment. In males it was not possible to carry out two-way logistic regressions using grid (6 grids) and trapping sessions (2 or 3 sessions, depending on whether the first was excluded) as factors because of insufficient degrees of freedom. In addition, simply assessing whether there were grid effects without considering seasonal changes made no biological sense (there were no simple grid effects - $\chi^2 = 7.73$, df 5, P = 0.17). Thus, the most robust analysis involved a 2-factor logistic regression involving trapping session versus PCB

level (high and low). There was a strong session effect ($\chi^2 = 62.25$, df = 2, $P < 0.0001$) but no evidence of a PCB effect ($\chi^2 = 0.0$) or an interaction effect ($\chi^2 = 3.95$, df 2, P = 0.14). In trapping sessions one, two, and three, 31.2% (N=16), 61.3% (N=75), and 5% (N=60), respectively, of the males were in breeding condition. Thus, changes in season, but not differences in PCB concentrations, explained the pronounced changes in male reproductive intensity.

In females, a similar analysis was carried out. There were no simple grid effects ($\chi^2 = 8.50$, df 5, P = 0.13). There was a strong session effect ($\chi^2 = 22.52$, df = 2, $P < 0.0001$) but no PCB effect ($\chi^2 = 0.22$, df 1, P =0.64) and no interaction effect ($\chi^2 = 4.04$, df 2, P = 0.09). In trapping sessions one, two, and three, 75% (N=12), 39.7% (N=58), and 12.3% (N=65), respectively, of the females were lactating. Thus, changes with season, but not differences in PCB concentrations, explained the pronounced changes in female reproductive intensity.

Body Mass Dynamics

Growth and body mass should reflect environmental conditions. In males, there was a significant effect of body weight on growth (F=9.66, df 1,21, P=0.005, Power = 0.86), no grid effect on growth rate (F=1.03, df 4,21, P=0.41, Power = 0.26; grid 3 was deleted as only one male was captured in both trapping sessions), and no interaction effect (F=1.02 df 4,21, P=0.42, Power = 0.26). Thus, as expected, smaller males grow faster than larger ones, but grids did not differ in growth rates. To assess whether there was an area effect, males were pooled based on where they were living (i.e. the northern two grids versus the southern four grids, as explained above) and on PCB level. There was a significant area effect of body weight (F=10.60, df 1,24, P=0.003, Power = 0.89), but no evidence of a PCB effect (F=1.09, df 1,24, P=0.31, Power = 0.16) or of an area effect (F=0.26, df 1,24, P=0.61, Power = 0.08); and all interaction effects were not significant. The area effect was that males on the northern grids were growing more rapidly than those on the southern grids.

In females, there was a significant effect of body weight on growth (F=4.88, df 1,21, P=0.04, Power = 0.55), no grid effect on growth rate (F=0.35, df 4,21, P=0.84, Power = 0.11; grid 4 was not included as only one female was captured in both trapping sessions), and no interaction effect (F=0.28 df 4,21, P=0.88, Power = 0.10). In the pooled analysis, all effects were nonsignificant (body weight - F=3.41, df 1,24, P=0.08, Power = 0.41; PCB - F=1.78, df 1,24, P=0.19, Power = 0.23; area - F=3.14, df 1,24, P=0.09, Power = 0.41; all interaction effects – nonsignificant). Thus, small animals grow more rapidly than large ones, but there is no evidence of either an area effect or of a negative effect of PCB levels.

Table 6 gives the mean body weights for all grids and trapping sessions. There was no relationship between PCB concentrations on a grid and body mass in either males (summer r=0.73, N=5, P=0.16, power=0.28 [grid 3 excluded because of low sample size]; autumn r=0.57, N=6, P=0.24, power=0.24) or females (summer r=0.67, N=6, P=0.15, power=0.33; autumn r=0.22, N=6, P=0.67, power=0.07). To reduce this complexity further, animals were pooled (sessions two and three only) based on where they were living (i.e. the northern two grids versus the southern four grids) and PCB level and a 2-way ANOVA was carried out. In males, there was a significant area effect (F=36.84, df 1,130, P < 0.0001), a significant PCB effect (F=20.00, df 1,130, P < 0.0001), and no interaction effect (F=0.75, df 1,130, P=0.39). In females, there was also a significant area effect (F=9.75, df 1,149, P = 0.002), but no PCB effect (F=0.41, df 1,149, P = 0.52) and no interaction effect (F=0.005, df 1,149, P=0.94). The significant effects were that males and females on the northern area weighed more than those on southern area, and that males, but not females, weighed more on high PCB sites (Fig. 3).

DISCUSSION

We tested the hypothesis that the population characteristics of *Blarina* living on more highly contaminated PCB sites should be more negatively affected than of *Blarina* living on less contaminated PCB sites. Our results provide no support for this hypothesis. There was no discernible effect of PCB level on population density (Fig. 2, Table 3), on survival (Table 4), on sex ratio (Table 5), on reproduction, or on growth. There was evidence of a PCB effect on mass in males (Table 6, Fig 3), but not females. However, for the latter result, the males on more highly contaminated sites weighed more, not less, than those on less contaminated sites. This is the opposite to expectations given results of other studies [e.g. 24].The correlation analysis between the above parameters and the degree of exposure to PCBs provided no evidence of a relationship between them; all correlations were nonsignificant and direction of the relationship in all cases but survival and male sex ratio were positive, not negative.

Our study assumed that *Blarina* living on PCB contaminated areas would carry PCB burdens reflective of the areas they were living on and hence that differential soil levels should result in differential burdens. Exposure was estimated based on spatially weighted average PCB concentrations in surface floodplain soil, not on PCB tissue burdens, as the focus of this study was on population demography and structure. We observed high site fidelity on the three sites trapped both before and after the late spring flood, low movement distances within a trapping session, and the absence of movement between grids 1 and 2. These factors indicate that exposure of shrews should directly reflect the local area where they were living and were trapped. Thus, we believe it is reasonable to conclude from our results that PCB exposure had no negative effects on the population characteristics we were able to measure.

Our intensive live-trapping methods clearly indicate that *Blarina* is one of the major small mammal species in these floodplain forests. The two previous studies on these floodplains failed to document the abundance and ubiquitous nature of *Blarina.* ChemRisk [31] trapped for 7 consecutive days in late August 1994 with 200 Sherman livetraps and 30 pitfalls on area of approximately 2 ha on the grid 5 site and caught no *Blarina;* one was caught on a nearby shrub meadow grid. TechLaw, Inc. [30] trapped for 5 consecutive days in mid September 1998 with 116 traps (100 snap traps and 16 pitfalls) and captured 24, 5, and 3 *Blarina* on areas on which we have estimated there were 39/ha (grid 1 - captured 35 different animals), 25/ha (grid 3 - captured 20), and 19/ha (grid 5 - captured 17), respectively in September (Fig. 2 and Table 3). Neither of the assessment methods in the former studies were comparable to ours and, for the TechLaw study, it is not possible to know how large an area their method actually sampled. Nevertheless, it appears the ChemRisk methodology may have been inadequate for assessing *Blarina* populations and that of TechLaw seriously undersampled them. One possibility why these studies failed to capture significant numbers of *Blarina* was that they were conducted when populations were low. Irregular, interannual fluctuations have been found in some *Blarina* populations living in forest habitats [55-57] whereas in grasslands, the fluctuations are annual only [58,59]. Given the 8 fold difference in number captured by TechLaw (3 to 24) in summer compared with our range of about 2 fold (17 to 35) for the same sites and given *Blarina's* presence in virtually all studies, the most likely explanation for the low numbers in the ChemRisk and TechLaw studies is severe trapping under representation.

Seasonal flooding and movements of animals between sites complicate the interpretations of some of our findings. Spring flooding along riverine habitats is a common yearly event in the eastern United States [35] and has been a constant feature in the landscape of New England at least from the period of European colonization onwards [36]. Previous studies have suggested that severe flooding lasting several weeks can cause drastic reductions in small mammal populations that then recover slowly by immigration from surrounding areas

[36,38,60]. However, Batzli [35] found that in the white-footed mouse, which can climb trees, adult survival was not affected by flood events, though successful reproduction declined. In contrast, *Blarina* does not climb trees and hence would have to leave flooded areas. Flooding in mid-April lasted about 2-3 weeks and would have resulted in emigration of *Blarina* away from the flooded sites. The flood in late May-early June 2001 was of much shorter duration (several days) but did result in our inability to trap three of the grids and also resulted in animals on grid 2 and possibly some of the *Blarina* on grid 1 having to disperse away temporarily. The flooding events in 2001 did prevent us from obtaining direct measures of on-site reproduction. However, other measures (density, intensity of reproduction, survival, sex ratio, growth and body weight dynamics) are robust and should give insight into the potential effects of PCB exposures on *Blarina* population characteristics.

It is also possible that we were sampling a transitory population of animals that failed to take up residence and thus failed to be exposed to local conditions for any length of time. Such conditions seem to prevail on grid 4, where survival between sessions two and three was low (Table 4), but density in each session was high (Table 3, Fig 1). Grid 4 had the highest numbers of meadow voles of any of the grids (Table 2) which was probably a direct consequence of dense patches of grass cover along the river. Thus the *Blarina* populations on this grid may have been more transitory because of lower habitat quality. Large scale immigration is likely to be the main explanation for the 8 fold increase in numbers seen on grid 1 between sessions one and two (Table 3, Fig. 2). However, survival was high thereafter, indicating that many of these animals became residents. It is most probable that grid 1 had not yet fully recovered prior to the first trapping session from the severe flood event of mid-April - early May. There are a number of lines of evidence to rule out continuous dispersal for most of our populations after the last flood event. There was no record of any dispersal between grid 1 and 2, even though they were only 100 m apart at the closest point. In addition, high survival on many of the grids (Table 4) indicates that the animals were taking up residence and remaining on the trapping grids. This corroborates the conclusions of Platt [61] that these animals are territorial and hence strongly attached to a particular site. Thus, we do not think these caveats compromise the conclusions of our study.

We have evaluated whether the findings of our study are comparable to results of other published population studies on *Blarina* and other small mammal species. Density estimates of *Blarina* vary enormously as a function of habitat. Near the northern limit of their range in the southern boreal forests of Manitoba, they reach a maximum density of 4.4/ha [62]. Further south in the hardwood forests of New Hampshire, they reach average densities of 14.5/ha [63]. In grasslands, densities can be similar to or higher than those found in woodland habitat. In bluegrass fields in Michigan, densities of about 2.5/ha were found [58]. In the 18-year study of Getz [34,59] in which three grassland habitats in Illinois were studied (bluegrass, alfalfa, and tallgrass) mean annual low densities ranged from 0.1 to 2.6/ha (in March) while mean annual peak densities ranged from 15.6 to 25.6/ha (in July to October). The highest number ever recorded during the 18 year period was 54/ha. In general, we recorded consistently higher densities in summer and autumn than any of the studies carried out in forested habitats and the densities on our grids usually exceeded those from studies carried out on grassland habitats as well. On our two northern grids (1 and 2), we recorded the highest densities (> 60/ha in July) ever reported in the literature. We attribute these high densities to our trapping technique, resulting in our density estimates being less confounded by high trapping-induced artifacts caused by mortality (e.g. 30% were found dead in the traps in the study of Blair [58] and 42.2% were found dead in the study of Getz's [59]). Moreover, if the ChemRisk [31] population estimates of the white-footed mouse (density of 16/ha) and the southern red-backed vole (8.7/ha) on the grid 5 forested site are reasonably accurate, then our estimates of *Blarina* densities

for this same site (which had the lowest densities of all our sites) still exceeded the estimates for those other individual species estimates (Fig.1, Table 3). In the floodplains of Illinois, Batzli [35] found densities of the white-footed mouse (10-20/ha in late summer) that were similar with those of the ChemRisk study. Thus *Blarina* is clearly a very major component of the small mammal community on the Housatonic floodplain. Our high densities and the lack of a differential PCB effect between high and low sites support the argument that the effects of PCB concentrations have not constrained *Blarina* populations in the 10-year floodplain.

There are very few survival estimates for *Blarina* from other studies and all of these are confounded by overnight trapping. Nonetheless, estimates from these studies will be used to compare to ours to give lower limits to what animals may experience in other settings. It is important to reiterate that all survival estimates include both on-site mortality and from-site dispersal and livetrapping studies cannot distinguish between them. Yahner [57] live-trapped shelterbelts in Minnesota for two years and found monthly survival rates of 71% with no change over the year. Getz [59] found that monthly survival ranged from an average of 33.4% per month in alfalfa fields to 47.5% in bluegrass fields. Most of our estimates are at least as high as those seen by Yahner [57] and up to twice those seen by Getz (Table 4). Our most robust spring estimate (given lack of potential flood impacts) comes from grid 5 and these are about 15% less than the late summer estimates of 74-80% for this grid. Grid 4 clearly is an outlier in the late summer, with survival being 20% lower than on almost all the other grids. However, this reduced survival is not associated with PCB concentration, as discussed above. Rather, this is likely to be indicative of high dispersal through the site and short residency on it, probably related to habitat-specific characteristics of the site. Thus, in general our shrew populations show high monthly survival, though there is grid-to-grid variability, but there is no evidence that this variability can be explained by differences in PCB concentrations among the grids.

Unequal sex ratios are common in studies on *Blarina,* with many reporting more males than females [58, 64, 65, 66]. In contrast, our results in session one were biased against males (38%) and thereafter on the four southern grids sex ratios were always less than 45%, with values of less than 40% being typical (Table 5). However, the two northern grids both were slightly biased in favor of males in sessions two and three, being 10% or higher than either of the other grids. Clearly there are site-specific differences, but these differences were not related to differences in survival (Table 4) or PCB concentrations (Table 1).

Reproduction of *Blarina* on the floodplain was largely restricted to spring and summer, tapering off in autumn. The small number of obviously pregnant females (N=3) may be related to our inability to detect pregnancies. However, both Dapson [66] and Christian [40] had low detection rates of pregnant females from large snap-trapped samples where pregnancies were determined from autopsy. Dapson suggested that pregnant females may withdraw temporarily from the population and thus move around less. Thus, the low number of

pregnant females from our live-trapping study may be an artifact and does not by itself indicate problems with reproduction. Our best evidence for reproduction comes from lactation in females (changes in male breeding condition basically echoing the changes seen in females) and in females lactation is observed predominantly in spring and summer. The best estimates of female reproduction in the literature come from Dapson's [66] snap-trapping study in the forests of New York and he found that virtually all reproduction was restricted to winter and spring, with very little occurring from July onwards. The winter reproduction echoes what Christian [40] found at another site in New York. These finding are generally consistent with ours, though 40% of our females were still lactating in July and only 12% by September. Thus, if most of the reproduction in our area is restricted to late winter and spring, production of young would be largely complete by summer and this should be reflected in population growth. Four of our six populations showed no marked growth from summer to fall and this may be a reflection of fewer recruits being present in the population (Fig. 2). Though we found no differences in reproduction that could be attributed to PCB effects, we could not determine the precise impact of PCBs on growth and survival of young born on site. Since *Blarina* do not enter traps until they are already large [59], a trapping study cannot directly measure on-site production of young or differentiate between animals born on site and those born off the site. However, we found no evidence of differences in growth rate associated with differences in PCB concentrations, and this argues that growth was not affected.

High quality habitat is typically associated with high population density, but higher density may be a misleading index and may actually indicate suboptimal conditions [67]. If suboptimal habitats are dispersal sinks where subordinate animals are forced to move when they have been driven from high quality habitats by population regulatory mechanisms, then these sinks may temporarily have higher density and exhibit wider fluctuations [68]. Linzey and Grant [27] report a possible example of this from a *Peromyscus leucopus* population living on a low-level contaminated PCB site in Pennsylvania (higher densities, higher turnover, and greater temporal variability). However, they concluded that factors other than PCB contamination could explain their results. It is important to note that their contaminated grid had PCB soil concentrations of only 0.3 ppm which was five times lower than our lowest contaminated grid (grid 6, Table 1). In our study, we found the highest densities and the only marked fluctuation in one area - the confluence area with the two northern grids. Three lines of evidence suggest that this area was an optimal, not a suboptimal, site. First, survival was high and similar on these grids relative to that on the southern ones (Table 4). Second, though sex ratio clearly favored males on the northern grids and females on the southern grids, this male bias on the northern grids was similar to that observed in virtually all other studies. Moreover, reproductive rates appeared to be similar on all sites. Third, average body mass was the highest on the northern grids (Table 6). Thus, this evidence is consistent with the interpretation that the highest density sites were indeed also the highest quality. One of these sites (grid 1) also had the second highest PCB concentrations (Table 1).

Finally, our study could not directly address the potential impact of maternal PCB loads on the production, survival, and subsequent reproduction of offspring on the floodplain. Two

difficulties stand in the way of resolving this. First, periodic flooding clearly prevents continuous, on-site residency of the animals and the floodplains and their adjacent nonflooded lands are involved in a periodic, dynamic interchange of individuals. Second, a characteristic of the biology of *Blarina* (i.e. young not entering traps until almost full grown) means we cannot know with any degree of certainty where young were born and thus we cannot track their fates and subsequent reproductive history relative to their maternity. More sophisticated techniques such as the use of radionuclides [69] or mitochondrial and microsatellite DNA analyses [70] would be required to establish maternity.

In conclusion, we found no evidence that variation in PCB concentrations among our trapping grids resulted in differences in population demography of *Blarina*. Our populations performed as least as well demographically as those living on uncontaminated sites and reported in the scientific literature. Densities were high, survival generally good, and other parameters within the range of the published literature. Thus, despite the presence of PCBs on these floodplains and despite the periodic flooding, these floodplains support healthy and abundant populations of *Blarina*.

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Tables

Table 1. Spatially weighted average concentrations of PCBs in the areas where the trapping grids were placed. Only sediment sample points within the trapping grids and within a 33 m buffer were included. Only concentrations collected within the top 15.24 cm of the soil horizon were used in the calculating these weighted averages.

Grid	Concentrations (ppm)	Number of Soil Samples
1	33.5	53
2	2.5	3
3	17.6	5
4	38.3	14
5	2.2	6
6	1.5	4

Table 2. Total number of different individuals caught between May to September 2001 in the Housatonic River study area. Traps were set for 3 days in each trapping session during daylight hours only.

Grid	Short-tailed Shrew	Meadow Vole	Pine Vole	White-footed Mouse	Southern Red-backed Vole	Eastern Chipmunk	Short-tailed Weasel	Red Squirrel	Meadow Jumping Mouse	Total
1*	60	50	0	13	1	10	0	0	0	134
2*	53	21	0	13	1	6	1	0	1	96
3**	28	1	0	1	2	13	0	0	4	49
4**	38	79	0	1	0	4	1	0	0	123
5*	33	0	3	2	1	0	0	0	0	39
6**	28	10	3	0	1	4	0	1	2	49
Total	240	161	6	30	6	37	2	1	7	490

"* Trapped in May-June, July, and September"
** Trapped in July and September only as flooding prevented trapping in May-June.

Table 3. Population densities (± 1 SE) per ha of *Blarina brevicauda* using the Jackknife estimator from CAPTURE for trapping grids on the Housatonic River below Pittsfield, Massachusetts, 2001.

	Trapping Session		
Grid	May-June	July	September
1	8 ± 2.6	67 ± 7.2	39 ± 3.5
2	18 ± 3.4	61 ± 7.1	26 ± 4.1
3		24 ± 4.5	25 ± 3.5
4		31 ± 5.2	36 ± 5.2
5	21 ± 3.6	22 ± 2.8	19 ± 1.8
6		23 ± 3.1	28 ± 3.5

Table 4. Survival of *Blarina brevicauda* per 30 days on six sites adjacent to the Housatonic River downstream of Pittsfield, Massachusetts. Note that a survival rate of 75% per 30 days means that half the population disappears every 72.3 days.

	Trapping Session							
	From May to July				From July to September			
Grid	Males		Females		Males		Females	
	%	N	%	N	%	N	%	N
1	0.0	1	80.8	3	74.5	21	67.7	17
2	76.4	5	33.4	8	63.9	19	53.1	17
3					100.0	1	63.5	14
4					38.6	13	40.5	6
5	64.4	10	55.7	5	79.5	11	74.2	9
6					76.2	8	83.2	11

Table 5. Sex ratio of *Blarina brevicauda* on the six trapping grids over the summer of 2001. Sex ratio expressed as the percentage of males (N= total sample size).

Grid	May -June		July		September	
	%	N	%	N	%	N
1	20.0	5	53.4	43	52.9	34
2	38.5	13	56.8	37	52.6	19
3			6.7	15	20.0	20
4			31.6	19	39.1	23
5	33.3	15	45.0	20	35.3	17
6			42.1	19	34.8	23

Table 6. Mean body masses (± 1 SE) of *Blarina brevicauda* on six grids along the Housatonic River between Pittsfield and Woods Pond, Massachusetts. Sample size in parentheses.

	Males			Females		
Grid	May-June	July	September	May-June	July	September
1	24.0 (1)	23.4 ± 0.6 (23)	23.9 ± 1.6 (18)	19.2 ± 1.6 (4)	20.4 ± 0.6 (21)	21.1 ± 0.5 (17)
2	21.2 ± 2.7 (5)	21.8 ± 0.6 (21)	22.8 ± 0.6 (10)	21.0 ± 1.6 (9)	20.0 ± 0.7 (16)	21.3 ± 0.8 (9)
3		19.0 (1)	19.8 ± 0.6 (4)		18.7 ± 0.9 (14)	19.0 ± 0.4 (16)
4		22.0 ± 0.7 (13)	21.8 ± 0.6 (9)		21.5 ± 1.2 (6)	19.5 ± 0.8 (13)
5	18.5 ± 1.0 (10)	19.6 ± 0.6 (9)	17.3 ± 0.6 (10)	18.2 ± 2.1 (4)	18.2 ± 1.0 (9)	18.3 ± 1.3 (6)
6		20.8 ± 1.2 (8)	19.5 ± 0.5 (8)		19.8 ± 1.1 (11)	19.3 ± 0.5 (15)

Figures

Figure 1 (a-f). Location of the six trapping grids along the Housatonic River between Pittsfield and Woods Pond, Massachusetts. See text for a description of each the grids. Fig. 1a gives the overview of the location of the grids along the river. Figs 1b to 1f are five figures in which the trapping grids have been superimposed on EPA site cover maps. The perimeter of each grid is outlined in black and the red dots on the perimeter were located by GPS. Fig. 1b covers grids 1 and 2, Fig. 1c covers grid 3, Fig. 1d covers grid 4, Fig. 1e covers grid 5, and Fig. 1f covers grid 6.

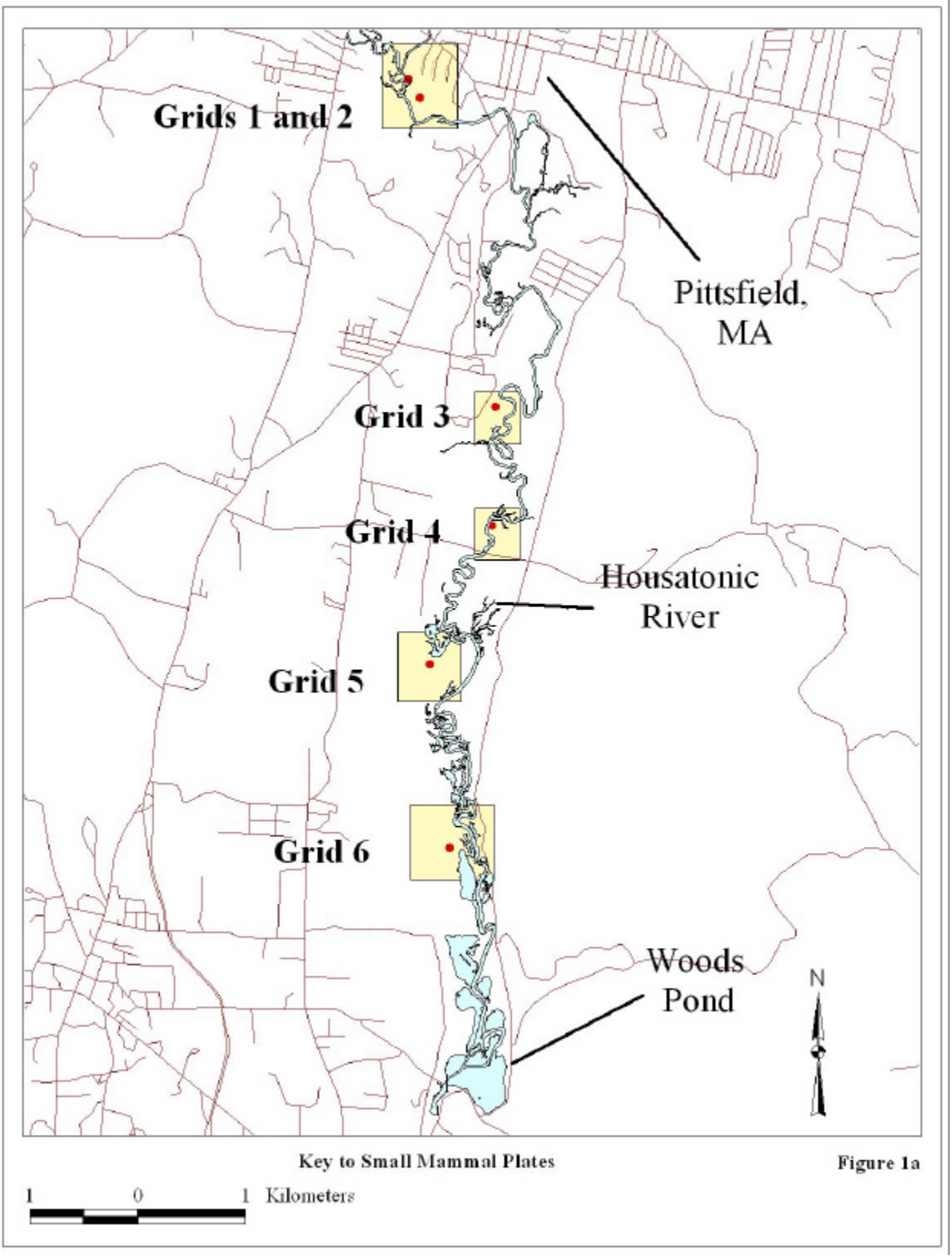
Grids 1 and 2
Pittsfield, MA
Grid 3
Grid 4
Housatonic River
Grid 5
Grid 6
Woods Pond
N
Key to Small Mammal Plates
1 0 1 Kilometers

Figure 1a

Small Mammal Sample location

Sample grids 1 and 2

Figure 1b

50 0 50 100 150 200 250 Meters

Legend

- Grid endpoints
- Outer boundary of sampling grid
- LOW: Lacustrine, Open Water
- PAB/UB: Palustrine, Aquatic Bottom/Unconsolidated Bottom
- PEM: Palustrine, Emergent
- PFO: Palustrine, Forested
- PFO/EM: Palustrine, Forested/Emergent
- PFO/SS: Palustrine, Forested/Scrub-Shrub
- PSS: Palustrine, Scrub-Shrub
- PSS/EM: Palustrine, Scrub-Shrub/Emergent
- PUB: Palustrine, Unconsolidated Bottom
- RAB: Riverine, Aquatic Bottom
- ROW: Riverine, Open Water
- SAND: Sand
- UPLAND: Upland
- WET_MEAD: Wet Meadow

June 28, 2002

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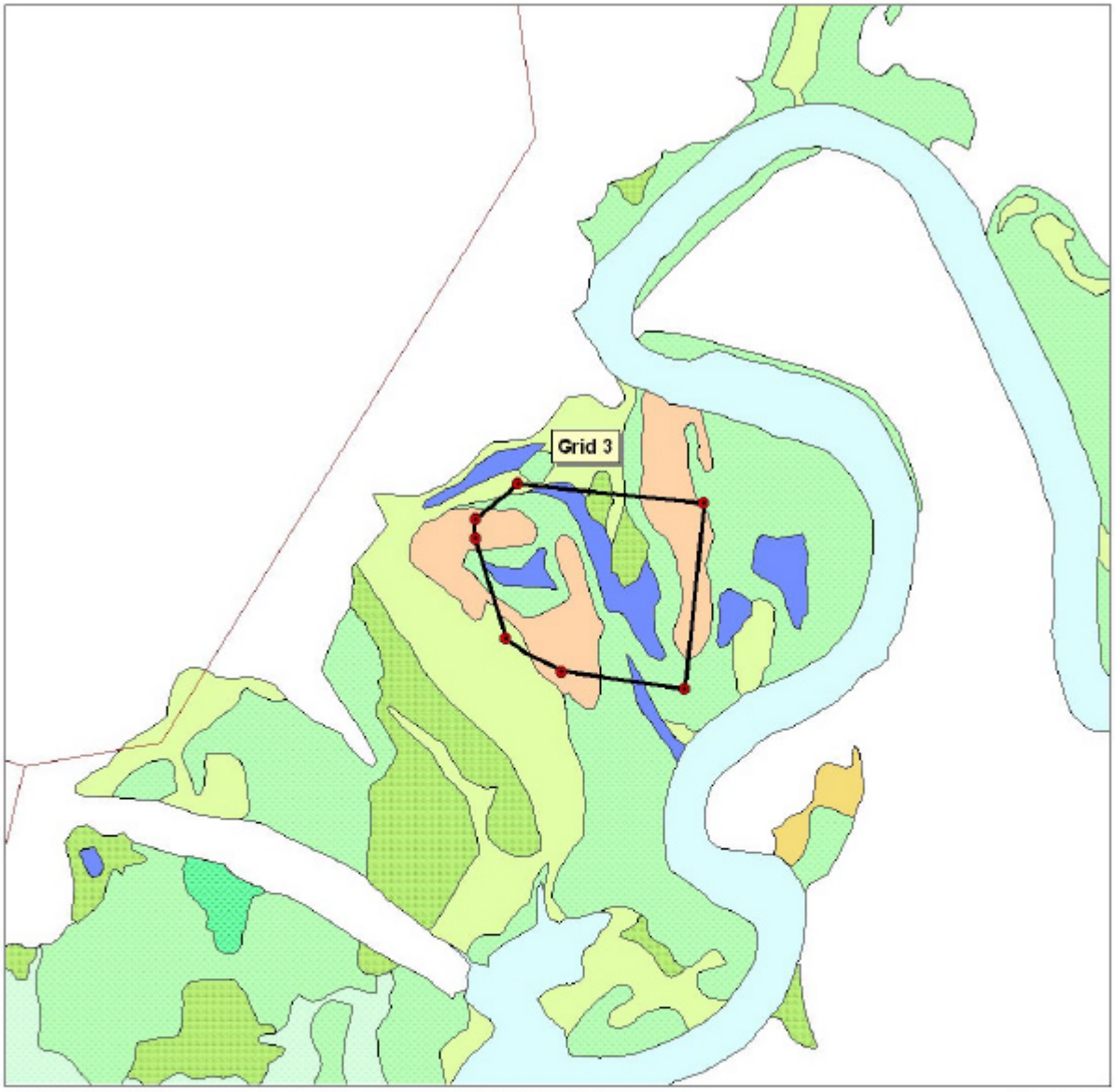

Small Mammal Sample location

Sample grid 3

Figure 1a

50 0 50 100 150 200 250 Meters

Legend

- Grid endpoints
- Outer boundary of sampling grid
- LOW: Lacustrine, Open Water
- PAB/UB: Palustrine, Aquatic Bottom/Unconsolidated Bottom
- PEM: Palustrine, Emergent
- PFO: Palustrine, Forested
- PFO/EM: Palustrine, Forested/Emergent
- PFO/SS: Palustrine, Forested/Scrub-Shrub
- PSS: Palustrine, Scrub-Shrub
- PSS/EM: Palustrine, Scrub-Shrub/Emergent
- PUB: Palustrine, Unconsolidated Bottom
- RAB: Riverine, Aquatic Bottom
- ROW: Riverine, Open Water
- SAND: Sand
- UPLAND: Upland
- WET_MEAD: Wet Meadow

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Small Mammal Sample location

Sample grid 4

Figure 1d

50 0 50 100 150 200 250 Meters

Legend

- Grid endpoints
- Outer boundary of sampling grid
- LOW: Lacustrine, Open Water
- PAB/UB: Palustrine, Aquatic Bottom/Unconsolidated Bottom
- PEM: Palustrine, Emergent
- PFO: Palustrine, Forested
- PFO/EM: Palustrine, Forested/Emergent
- PFO/SS: Palustrine, Forested/Scrub-Shrub
- PSS: Palustrine, Scrub-Shrub
- PSS/EM: Palustrine, Scrub-Shrub/Emergent
- PUB: Palustrine, Unconsolidated Bottom
- RAB: Riverine, Aquatic Bottom
- ROW: Riverine, Open Water
- SAND: Sand
- UPLAND: Upland
- WET_MEAD: Wet Meadow

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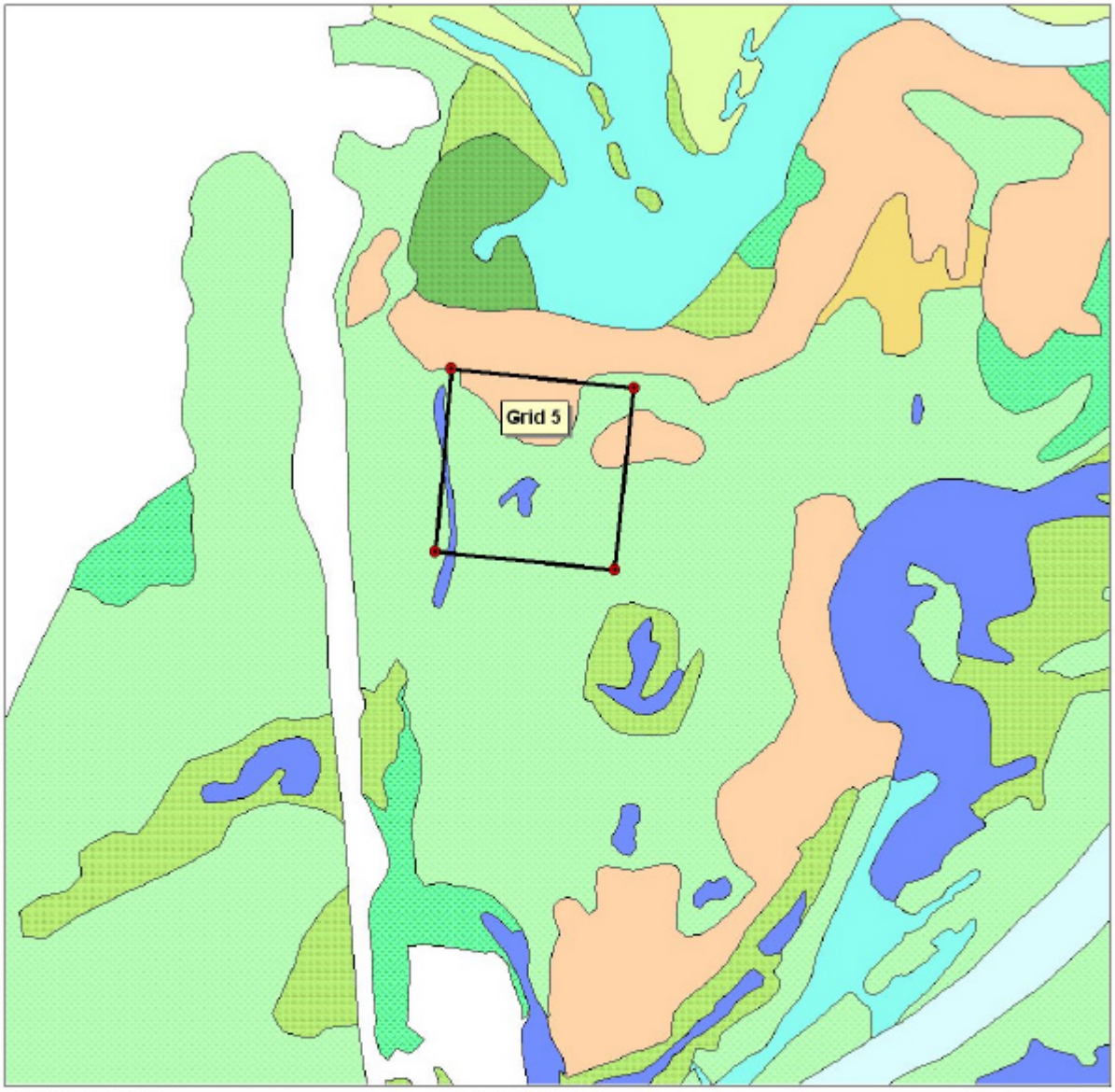

Small Mammal Sample location

Sample grid 5

Figure 1a

50 0 50 100 150 200 250 Meters

Legend

- Grid endpoints
- Outer boundary of sampling grid
- LOW: Lacustrine, Open Water
- PAB/UB: Palustrine, Aquatic Bottom/Unconsolidated Bottom
- PEM: Palustrine, Emergent
- PFO: Palustrine, Forested
- PFO/EM: Palustrine, Forested/Emergent
- PFO/SS: Palustrine, Forested/Scrub-Shrub
- PSS: Palustrine, Scrub-Shrub
- PSS/EM: Palustrine, Scrub-Shrub/Emergent
- PUB: Palustrine, Unconsolidated Bottom
- RAB: Riverine, Aquatic Bottom
- ROW: Riverine, Open Water
- SAND: Sand
- UPLAND: Upland
- WET_MEAD: Wet Meadow

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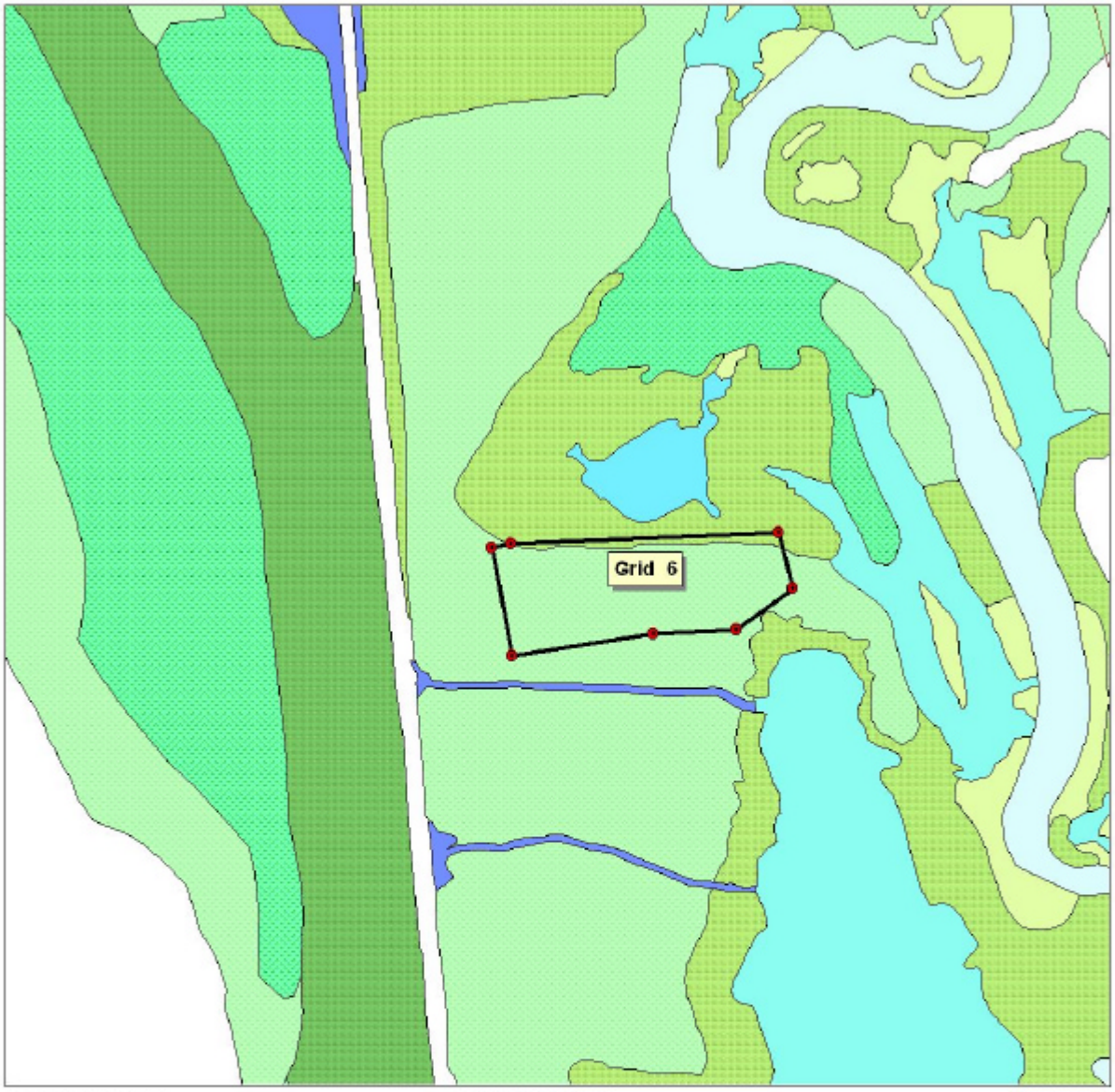

Small Mammal Sample location

Sample grid 6

Figure 16

50 0 50 100 150 200 250 Meters

Legend

- Grid endpoints
- Outer boundary of sampling grid
- LOW: Lacustrine, Open Water
- PAB/UB: Palustrine, Aquatic Bottom/Unconsolidated Bottom
- PEM: Palustrine, Emergent
- PFO: Palustrine, Forested
- PFO/EM: Palustrine, Forested/Emergent
- PFO/SS: Palustrine, Forested/Scrub-Shrub
- PSS: Palustrine, Scrub-Shrub
- PSS/EM: Palustrine, Scrub-Shrub/Emergent
- PUB: Palustrine, Unconsolidated Bottom
- RAB: Riverine, Aquatic Bottom
- ROW: Riverine, Open Water
- SAND: Sand
- UPLAND: Upland
- WET_MEAD: Wet Meadow

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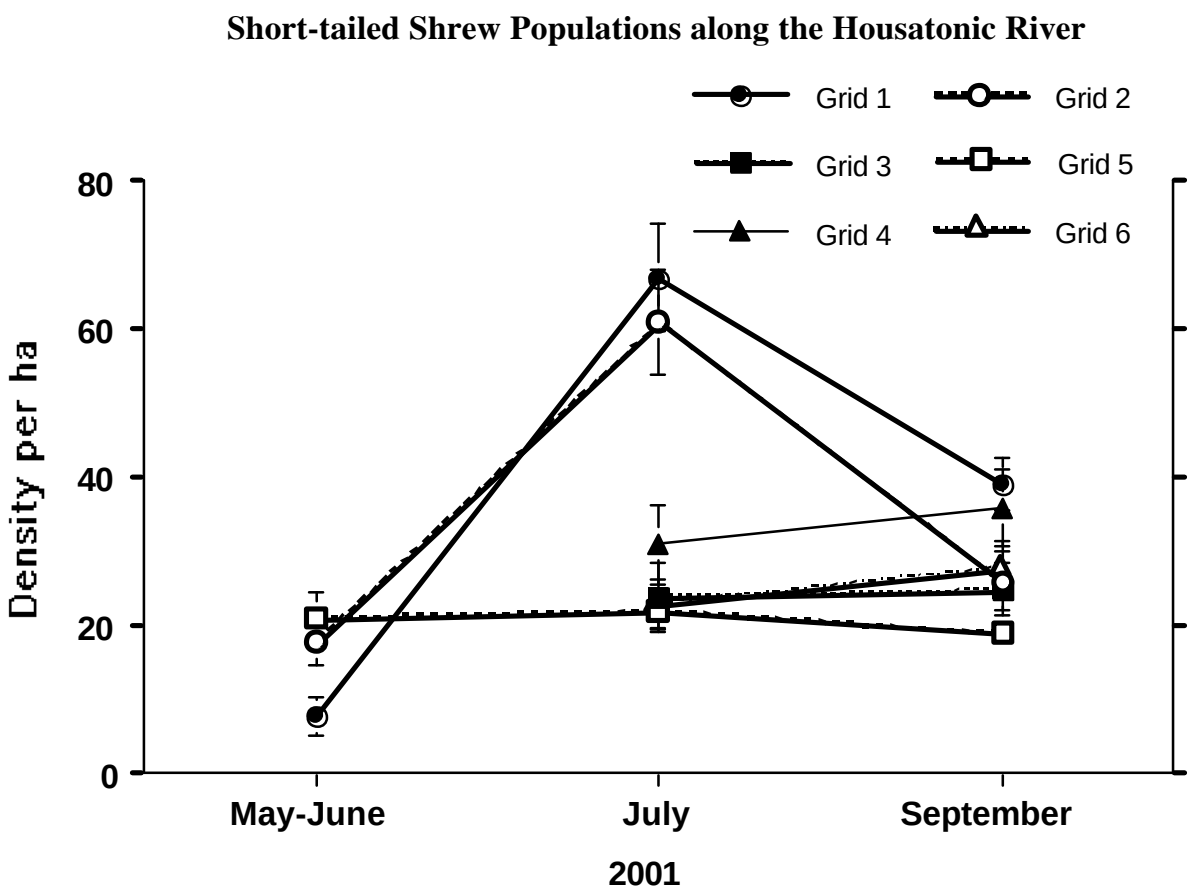

Figure 2. Population densities (± 1 SE) per ha of *Blarina brevicauda* in 2001 on six live-trapping grids along the Housatonic River, Massachusetts between Pittsfield and Woods Pond. Three of the grids (solid symbols) were located on sites with high PCB concentrations and three (open symbols) were on sites with low PCB concentrations. Points without error bars have very narrow SE values obscured by the point itself.

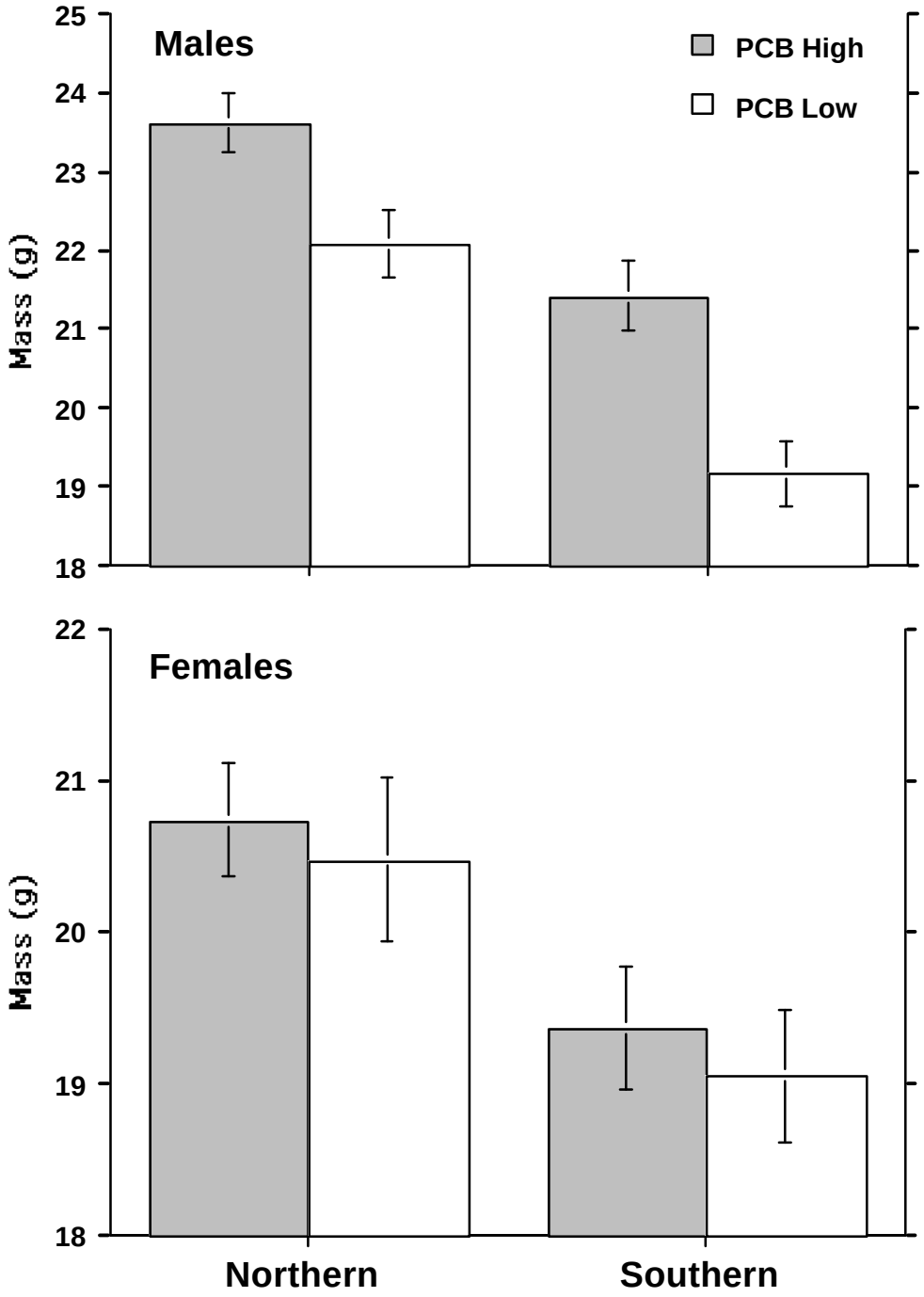

Figure 3. Mean (± 1 SE) body mass of male and female *Blarina brevicaud*a. Data from trapping sessions two and three were pooled and animals were distinguished based on whether they were caught on the northern grids (grids 1 and 2) or the southern grids (the rest) and whether they were caught on high or low PCB contaminated sites.